Improving Models of Forest Carbon and Water Cycling: Revisiting Assumptions and Incorporating Variability

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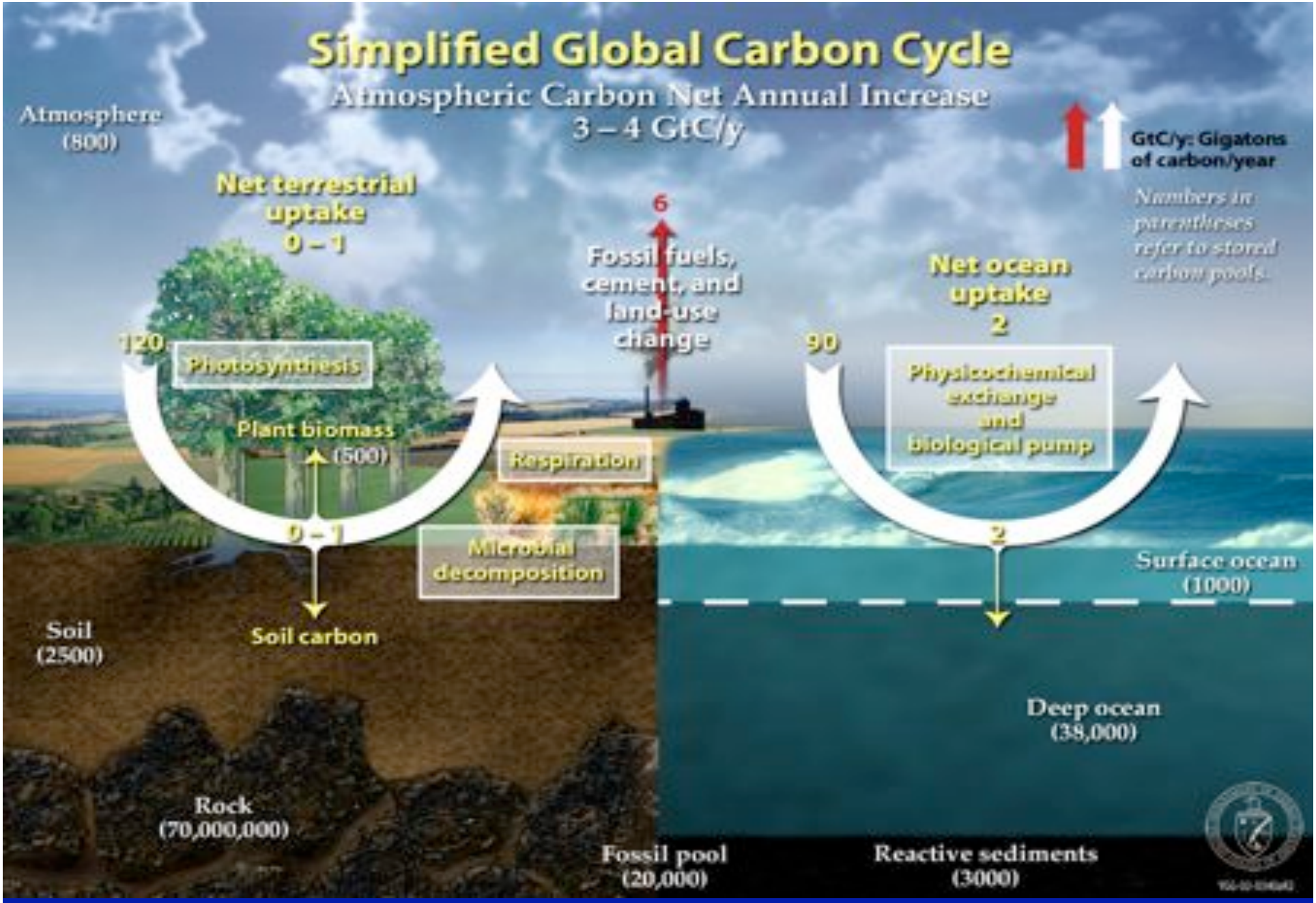
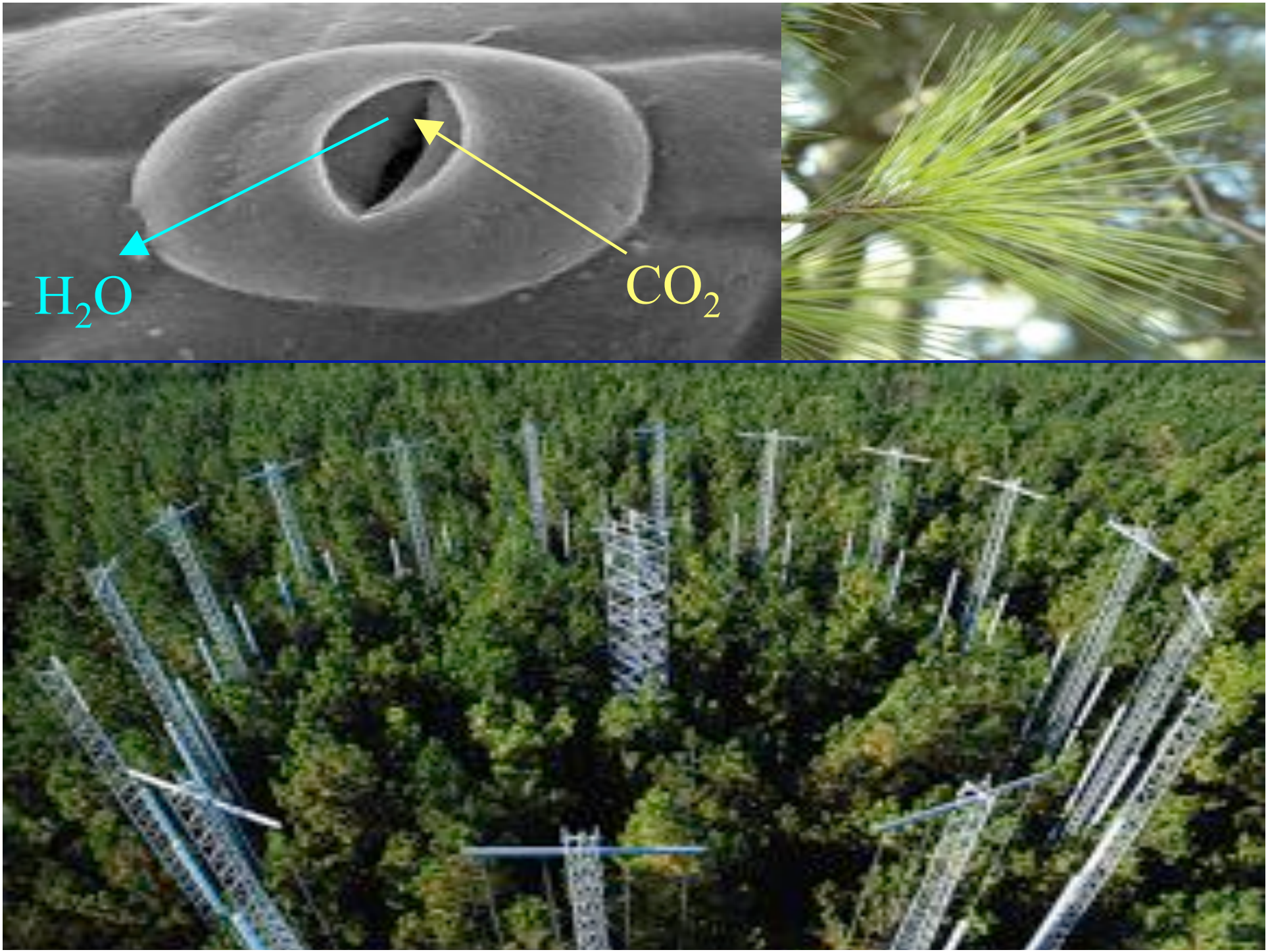
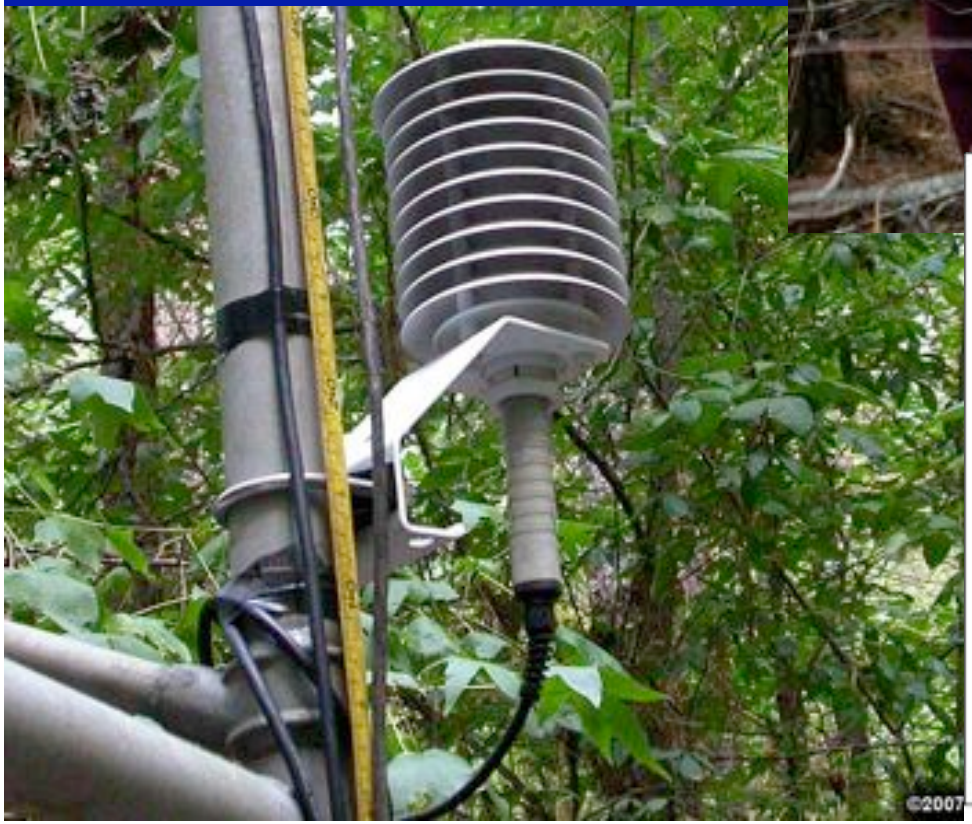
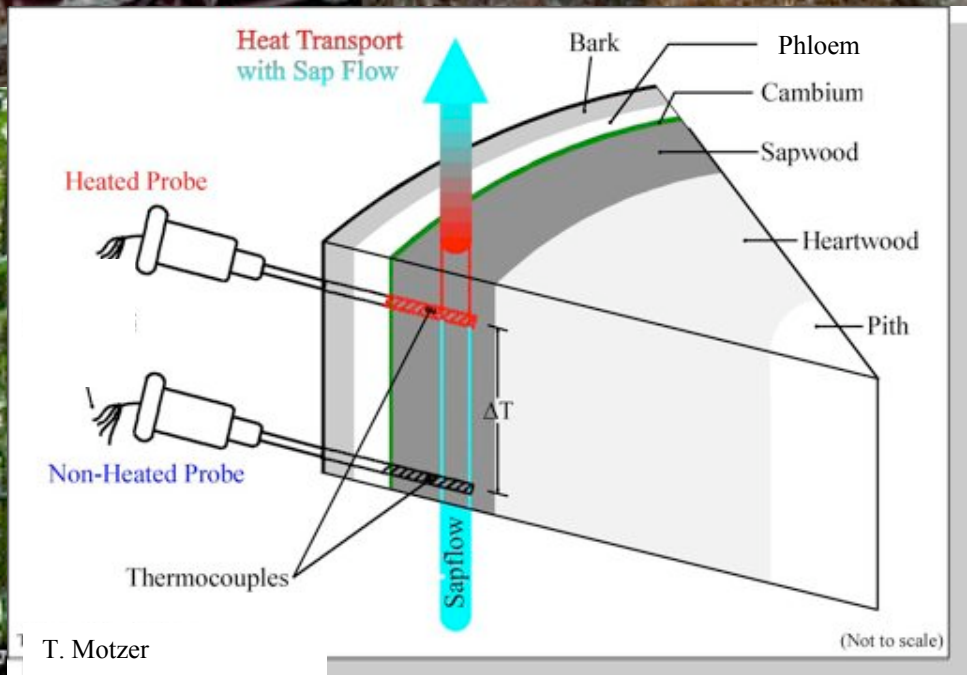


IPCC AR4 NPP response to doubling of [CO_2]: +12-76%


H_2O
CO_2

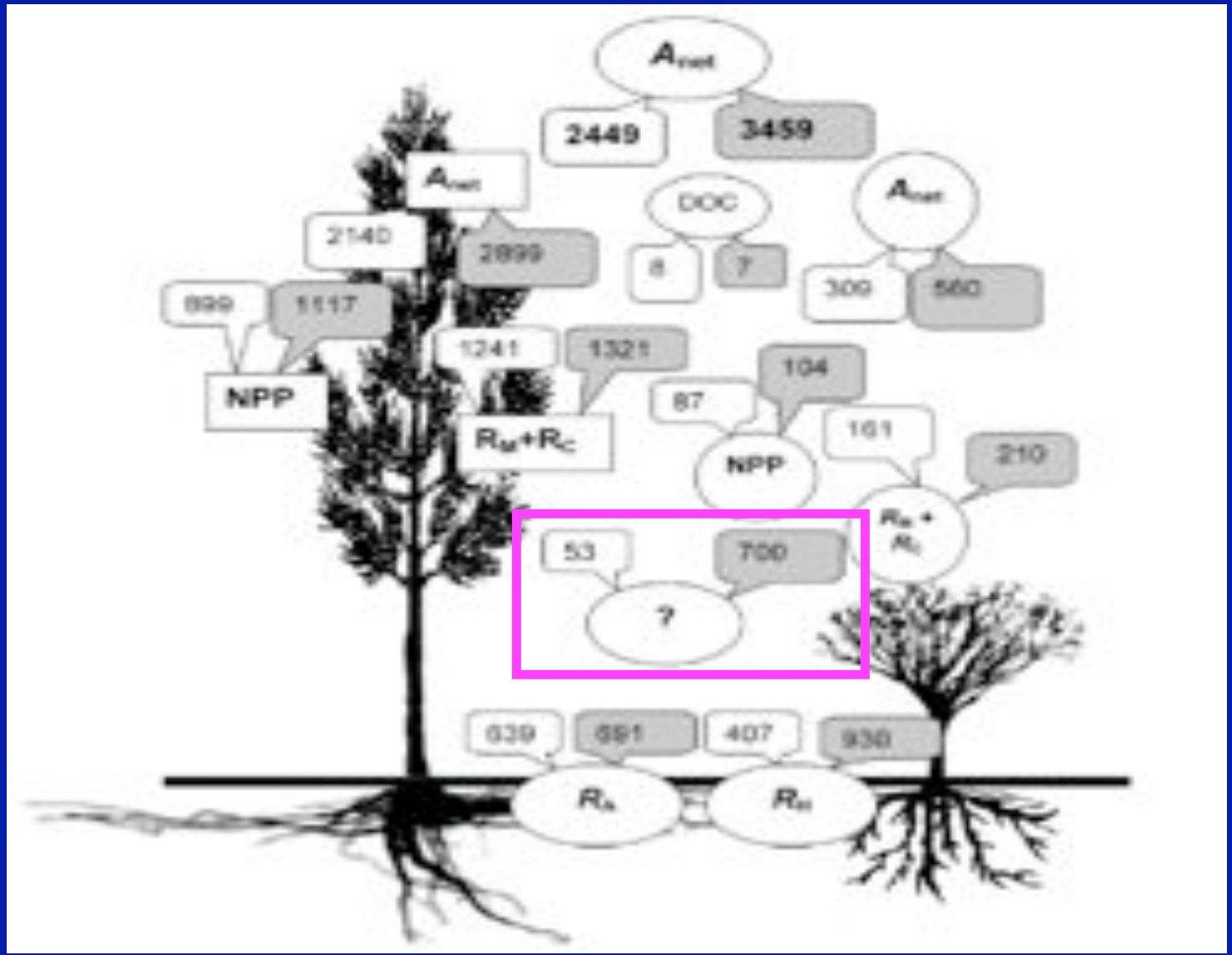
Fast Fluxes
Slow Growth





T. Motzer

How close is close? Bias vs. Variability



From Schäfer et al. 2003

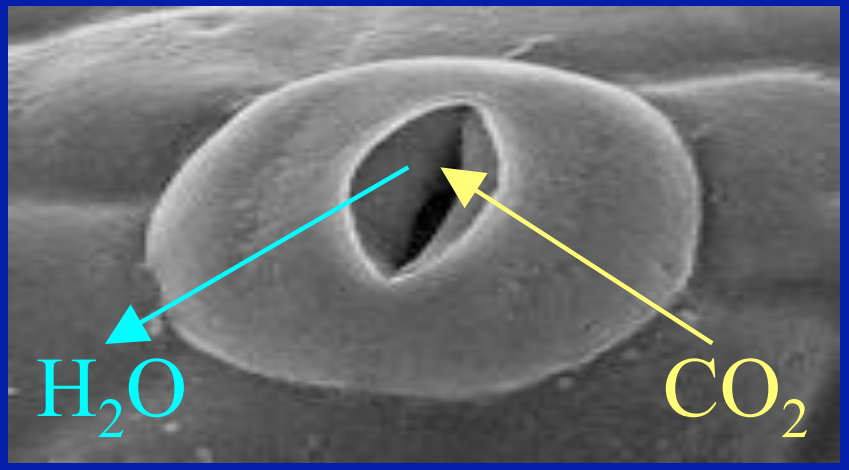
Improving Models of Forest Carbon and Water Cycling

- Incorporating Variability
  - Fast Fluxes, Slow Growth
  - How Close is Close?
  - Model Structure
  - Data Distributions
  - Using Parameter Distributions
- Evaluating Assumptions
  - Nighttime T & Flux Magnitudes
  - Water Storage & Flux Time Lags
  - New Sampling
- Extensions to Other Data

Modeling Photosynthesis Using 4CA:
Canopy Conductance Constrained Carbon Assimilation

$$A_N = g_{sc}(c_a - c_i) = g_{sc}\left(1 - \frac{c_i}{c_a}\right)$$

$g_{SC} \geq g_{crit}$ and
$PPFD > Q_S$?



YES

NO

$$c_i/c_a = \overline{c_i/c_a}$$

$$c_i/c_a = f(PPFD, g_{SC})$$

Picture: J. R. Thomasson, Fort Hays State University

Measurements Contributing to Photosynthesis Calculation

A_{NC}

Measurements Contributing to Photosynthesis Calculation

Env. Conditions
(Stand Scale)

A_{NC}

Measurements Contributing to Photosynthesis Calculation

Env. Conditions
(Stand Scale)

Leaf Area
(Stand Scale)

A_{NC}

Measurements Contributing to Photosynthesis Calculation

Env. Conditions
(Stand Scale)

Water Use
(Tree Scale)

Leaf Area
(Stand Scale)

A_{NC}

Measurements Contributing to Photosynthesis Calculation

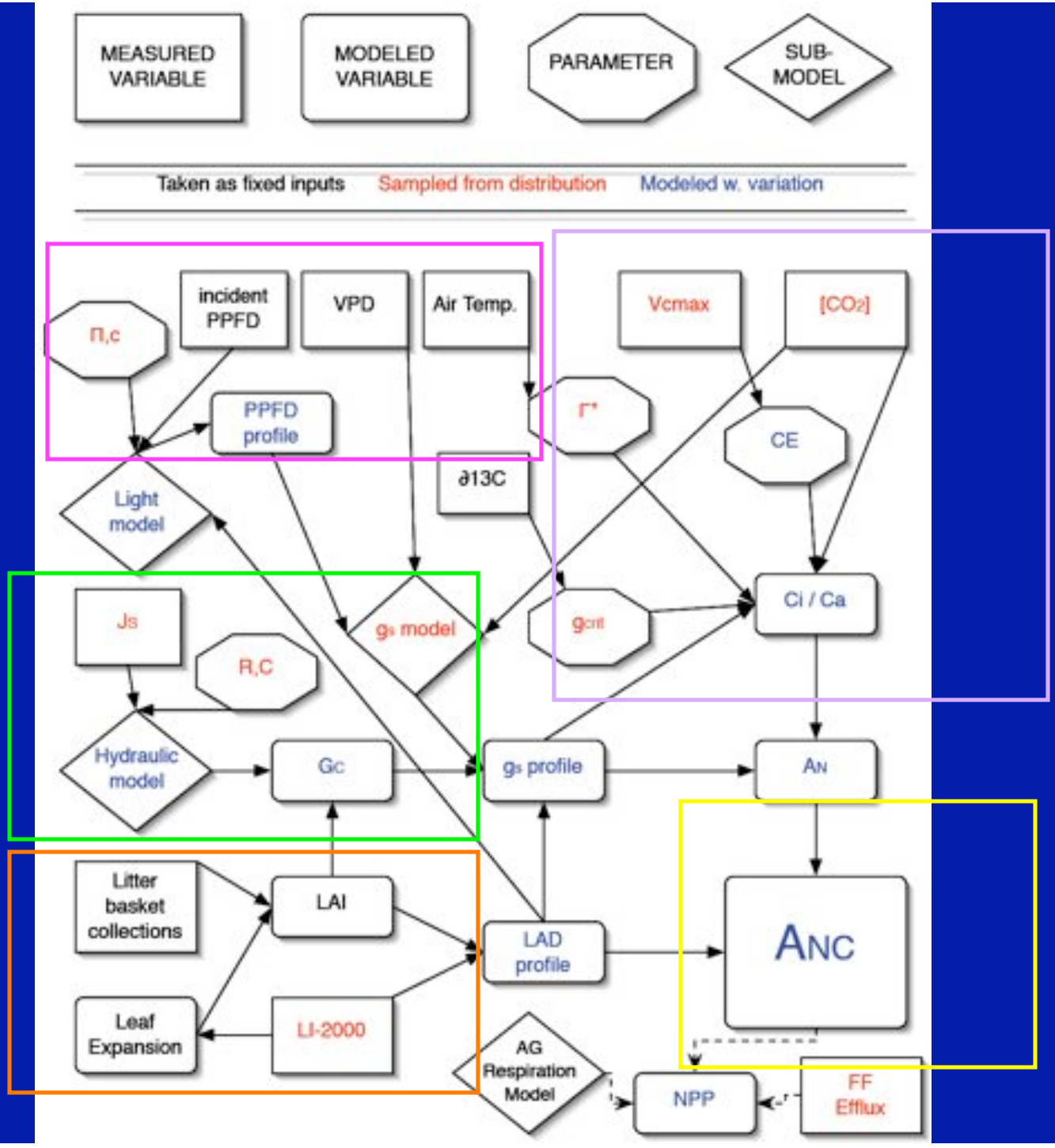
Env. Conditions (Stand Scale)

Photosynthetic Responses (Leaf Scale)

Water Use (Tree Scale)

Leaf Area (Stand Scale)

A_{NC}


MEASURED VARIABLE
MODELED VARIABLE
PARAMETER
SUB-MODEL
Taken as fixed inputs
Sampled from distribution
Modeled w. variation
incident PPFD
VPD
Air Temp.
Vcmax
[CO2]
Π,c
PPFD profile
Γ*
CE
∂13C
Light model
Ci / Ca
Js
gs model
gcrit
R,C
Hydraulic model
Gc
gs profile
An
Litter basket collections
LAI
LAD profile
ANC
Leaf Expansion
LI-2000
AG Respiration Model
NPP
FF Efflux

Diffuse Radiation

MEASURED VARIABLE | MODELED VARIABLE | PARAMETER | SUB-MODEL

Taken as fixed inputs | Sampled from distribution | Modeled w. variation

Branch Imaging

Porometry

Database

Π,c
incident PPFD
VPD
Air Temp
Vcmax
[CO2]
Γ*
CE
PPFD profile
∂13C
Light model
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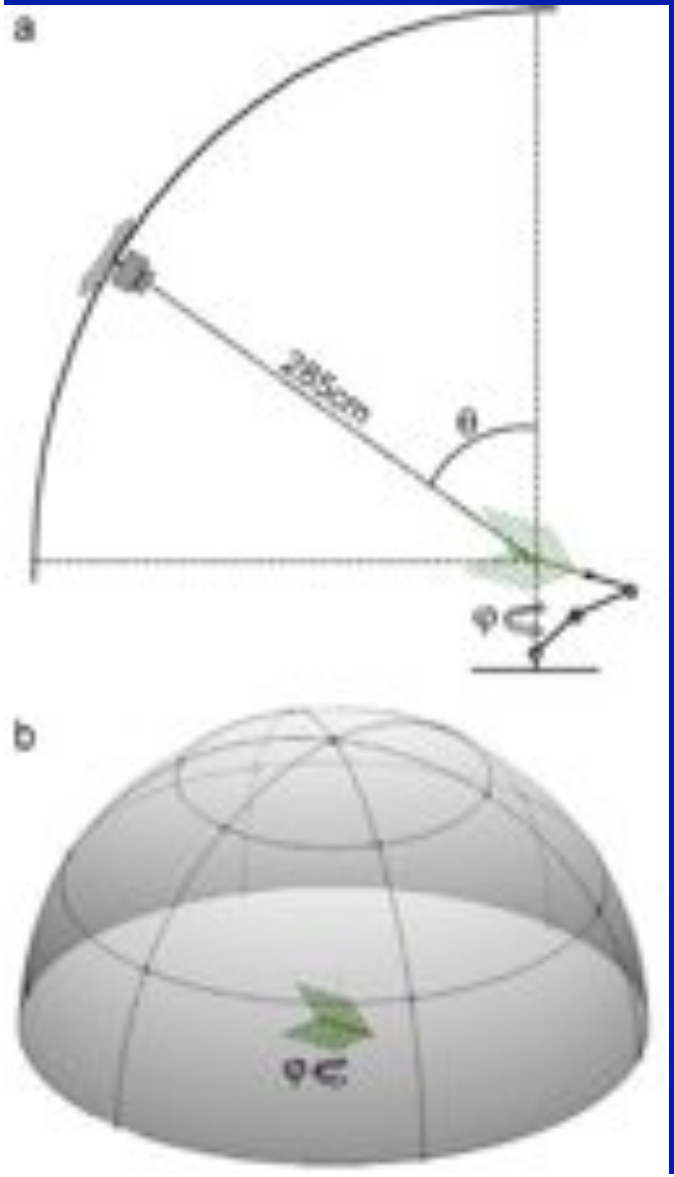
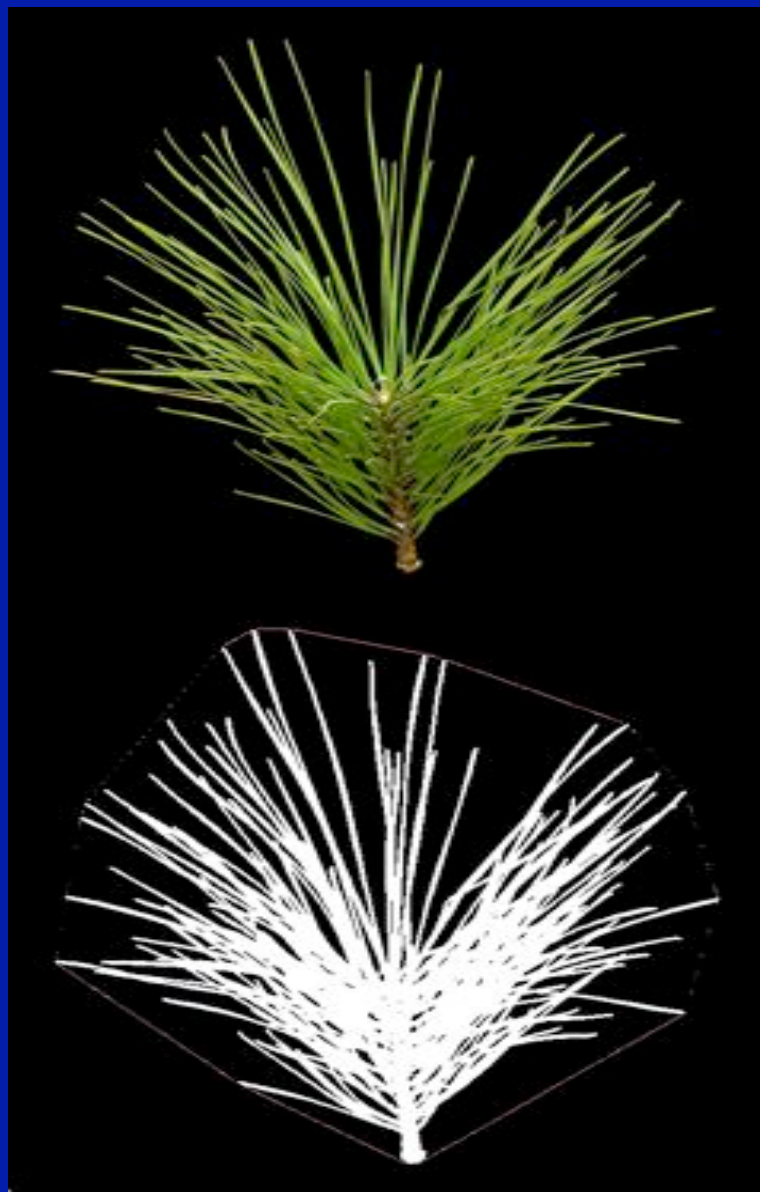
Branch Imaging (M. Thérézien)



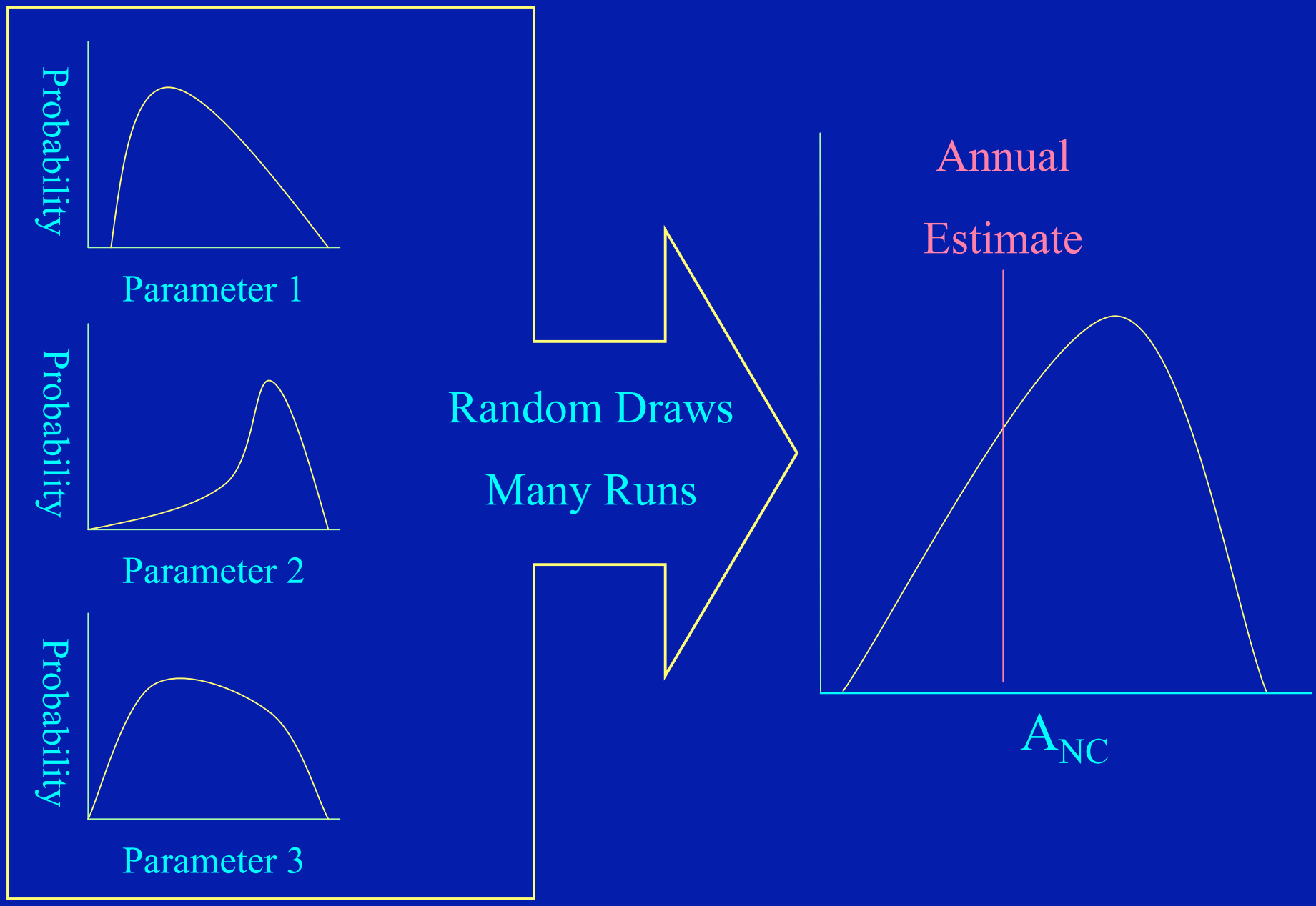
Light Model Parameters

Spherically Averaged for 10 sun & 10 shade branches

STAR * 4 = Π



Incorporating Variability



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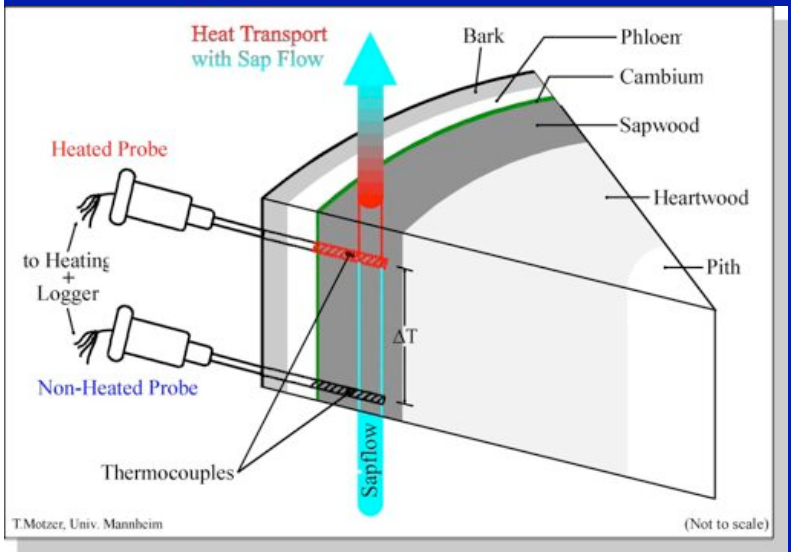
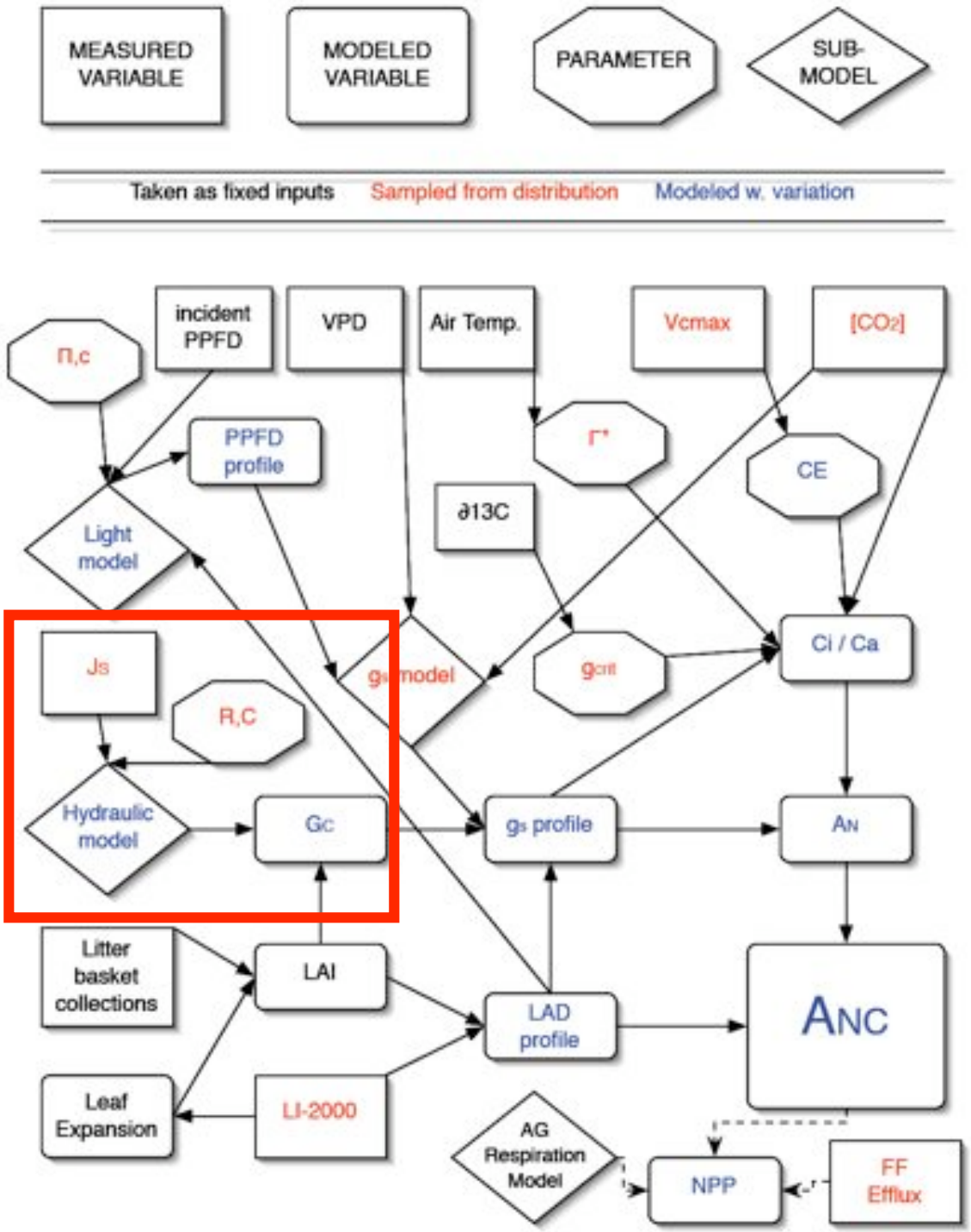
Sap Flux in 4CA model

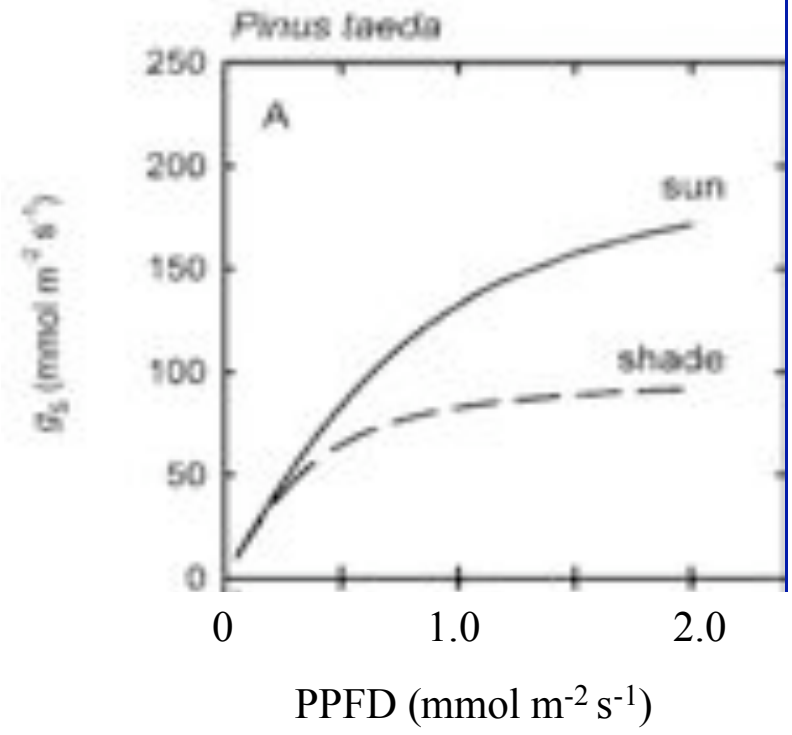
- Constrains assimilation
- 'Zero flow' calibration
- Usually measured at breast ht.
- Radial variation
- Integrates over entire leaf area distal to sensor

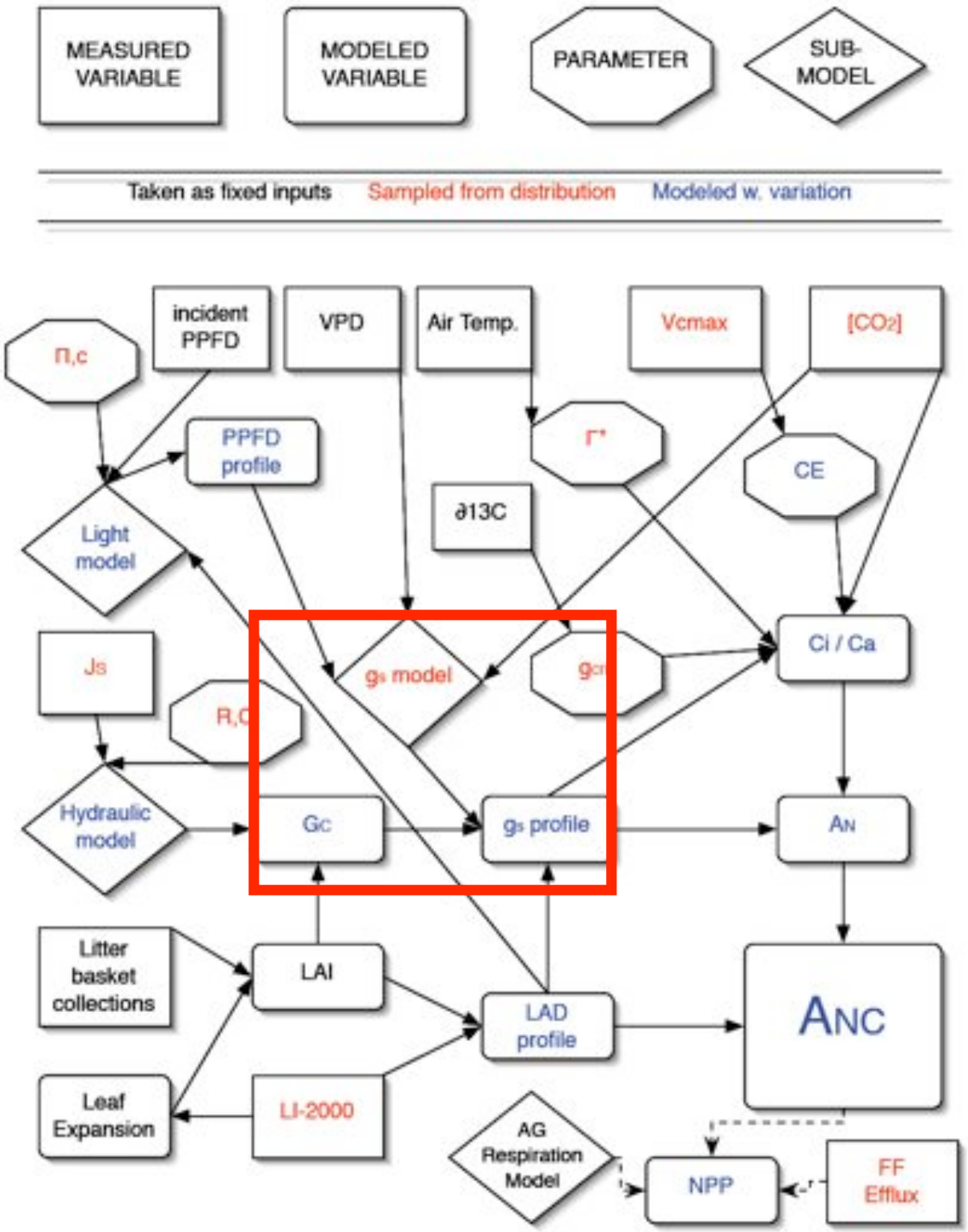




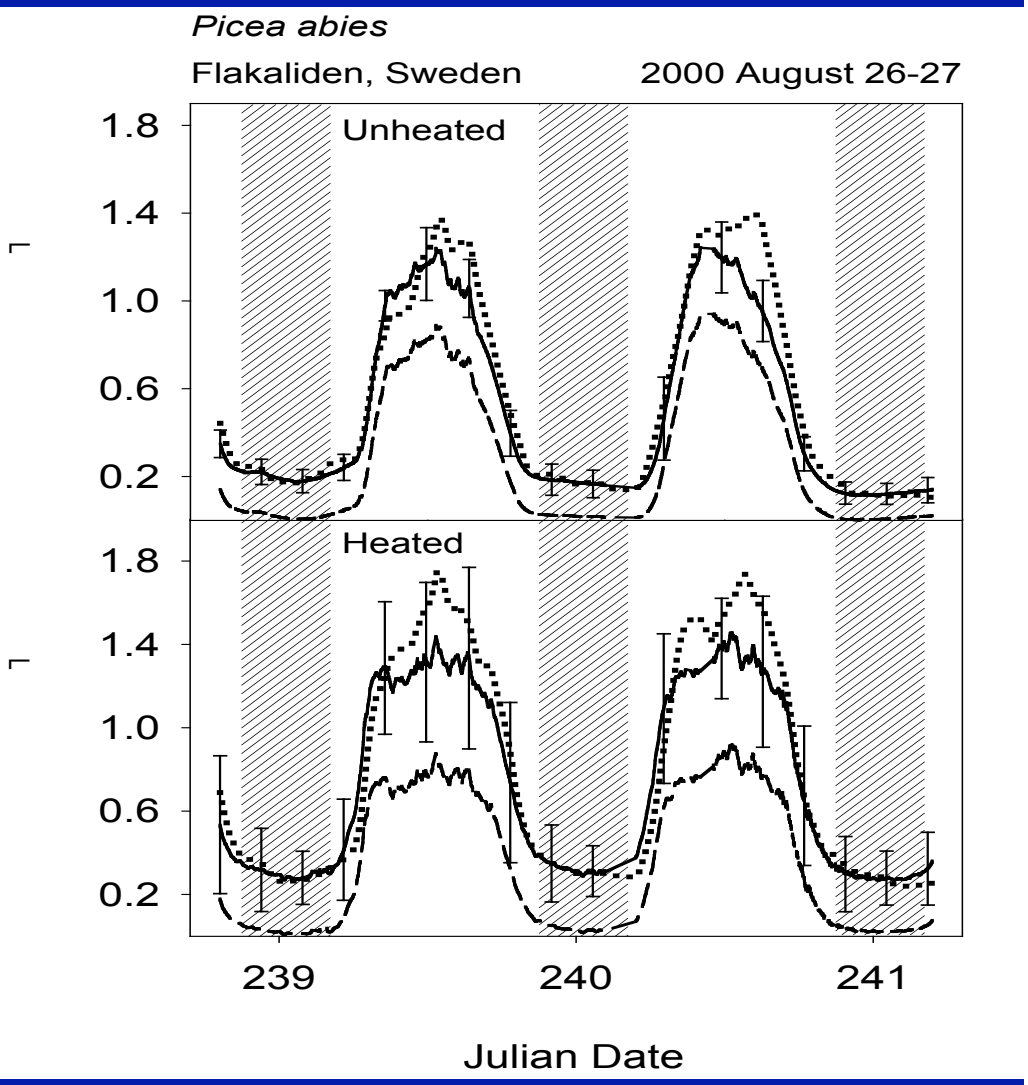
Leaf Light Responses

- Partition canopy conductance to canopy layers
- Yet to be checked against profiles of sap flux within crown



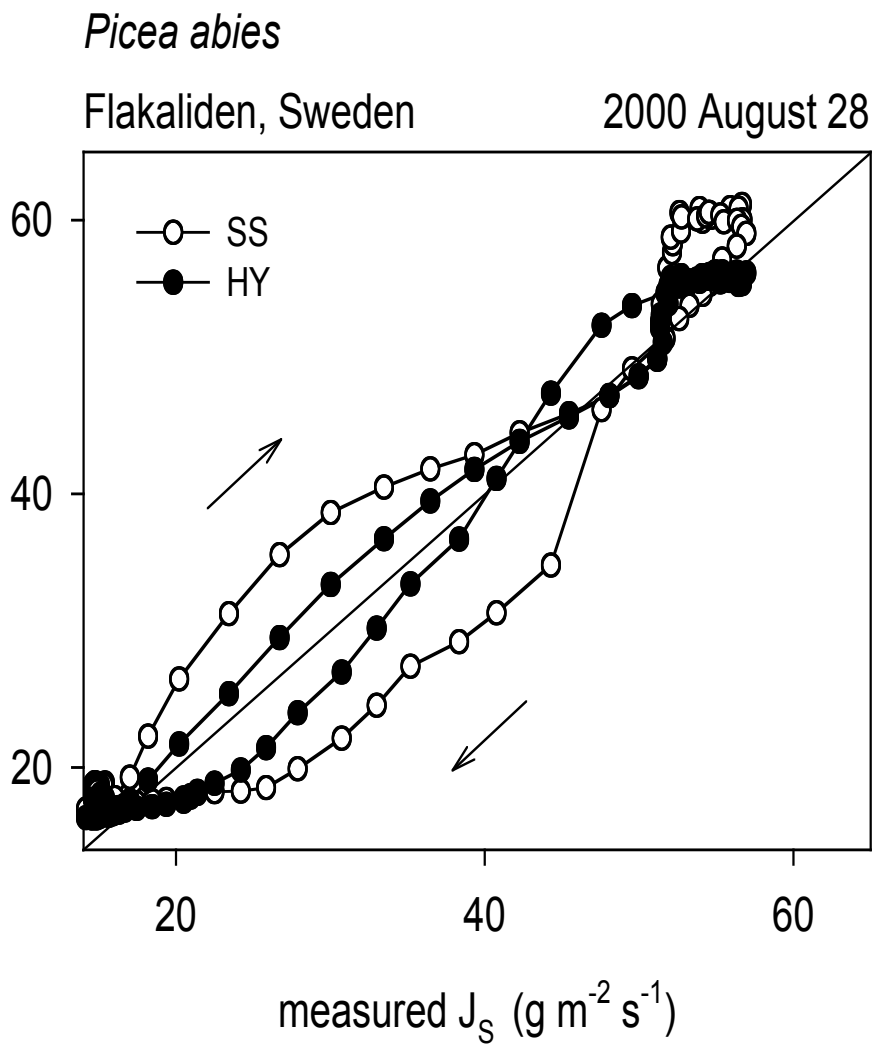


Sap Flux Estimates : Effect of Nighttime Transpiration



Ward, Oren, Sigurdsson, Jarvis and Linder. 2008. Tree Physiology 28 (4).

Sap Flux Estimates: Effect of Water Storage



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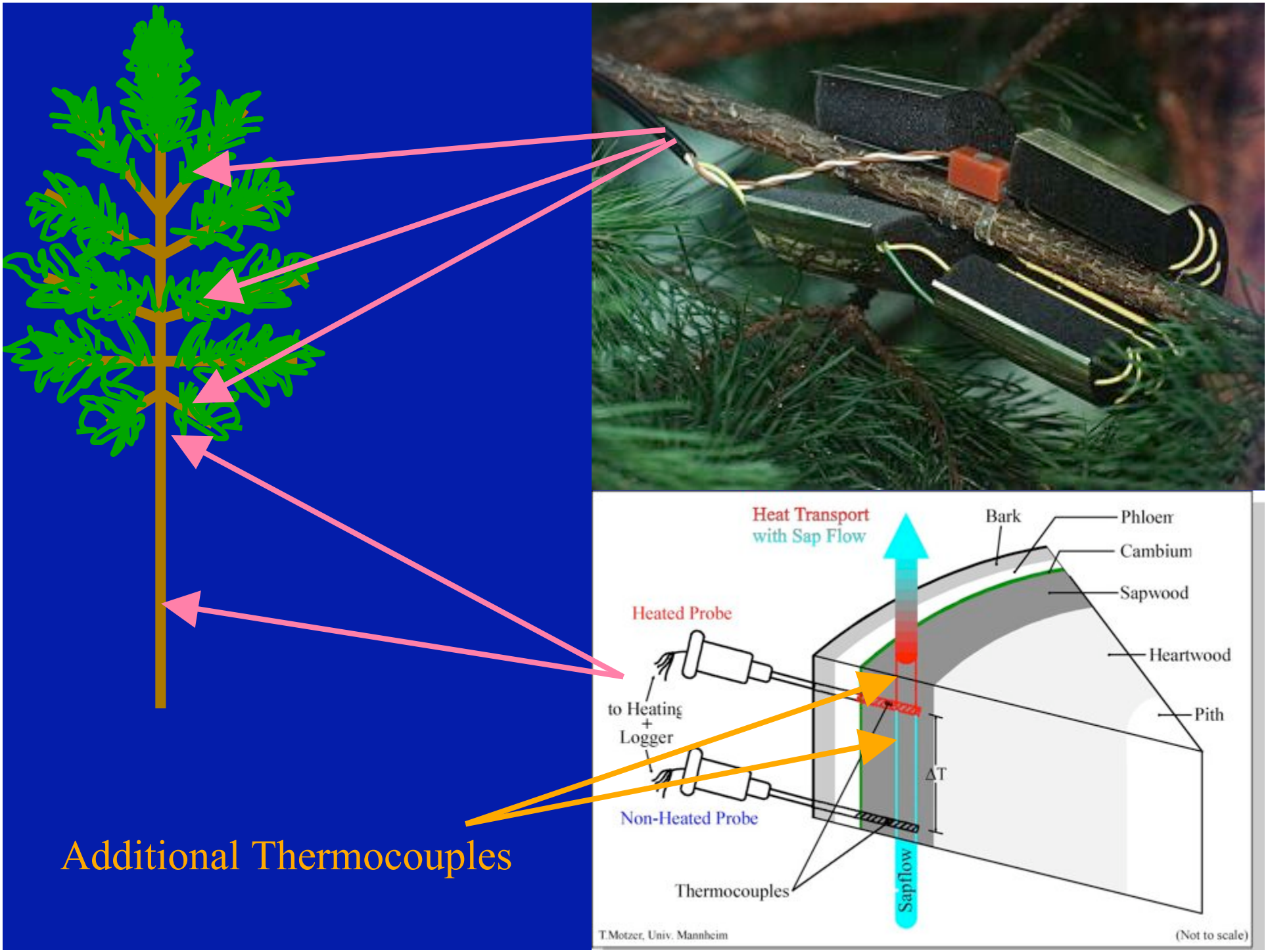
Sap Flux Estimates: Effect of Water Storage

	Ambient–Control	Ambient–Fertilized	Elevated–Control	Elevated–Fertilized
$\tau = C_{leaf}/K_{leaf}$	11.1 ± 0.6 a	10.5 ± 0.9 a	14.0 ± 1.1 b	15.6 ± 1.0 b

Domec, Palmroth, Ward, Maier, Thérézien and Oren (In Review)

New Sampling

- Profiles of Sap flux (BH, BLC, 3 whorls)
  - 12-16 trees (3-4 per treatment)
  - Time lags, capacitance
  - Gs partitioning
  - Modifications to detect zero flow
- Porometry (Light Curves)
  - Gs partitioning
  - Nighttime conductance at 1 kPa VPD
- Branch Chambers
  - Nighttime stomatal response to VPD


Heat Transport
with Sap Flow
Bark
Phloem
Cambium
Sapwood
Heartwood
Pith
Heated Probe
to Heating
+
Logger
Non-Heated Probe
ΔT
Thermocouples
Sapflow
T.Motzer, Univ. Mannheim
(Not to scale)
Additional Thermocouples

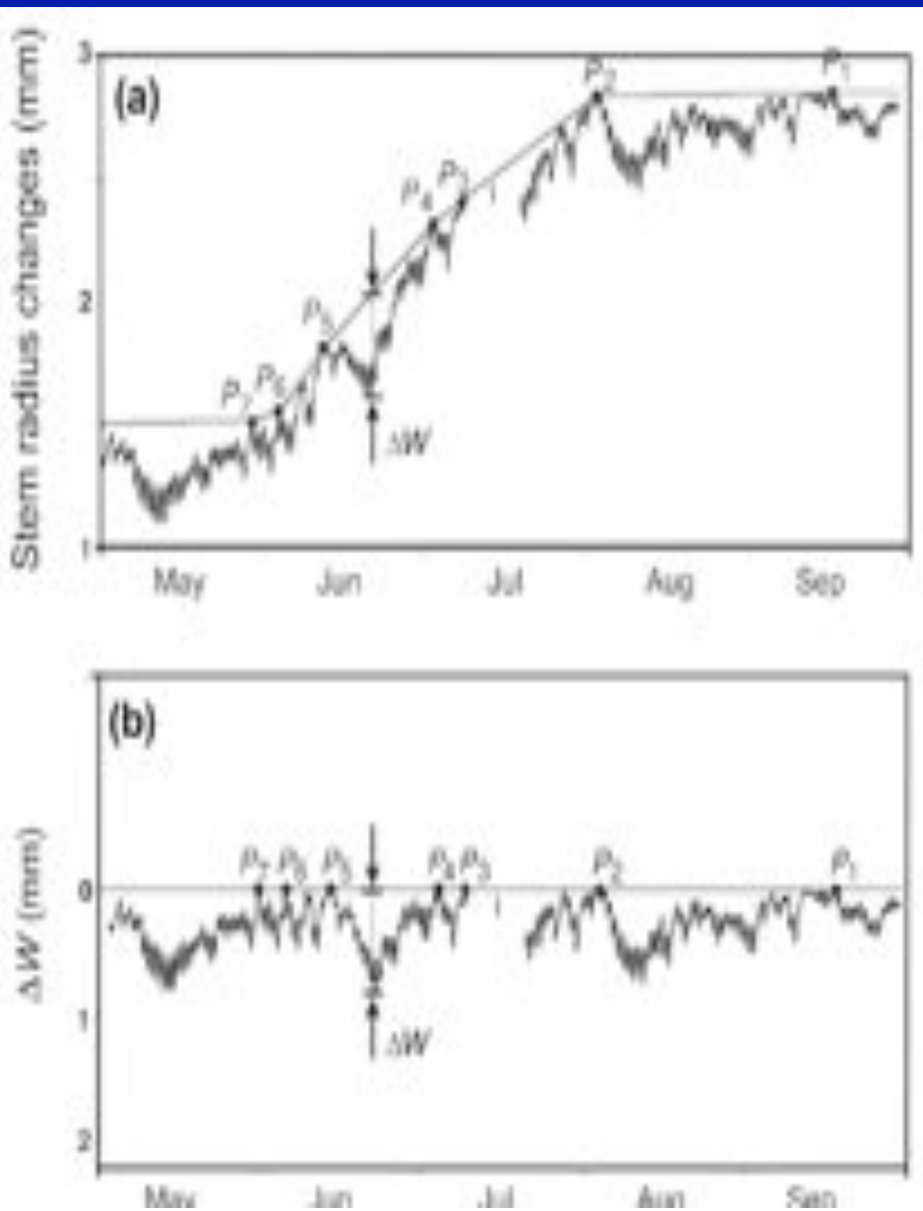
Other Data Sets

- Cross Site Comparison
  - Duke and ORNL

Also, to what can we relate short term estimates of Anet?

Photosynthesis, Stem Respiration & Growth

R. Zweifel



A.C. Oishi

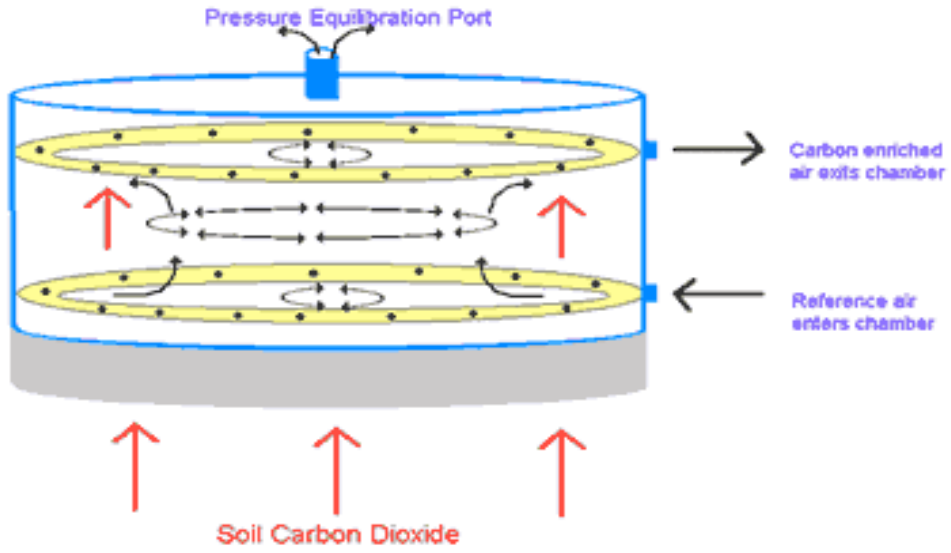
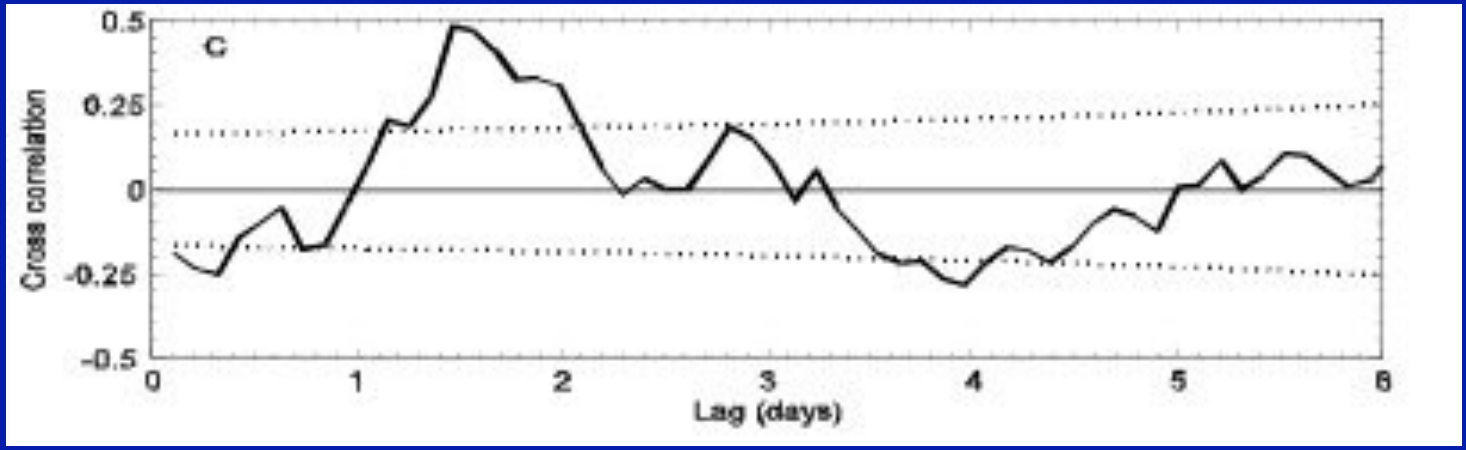


Figure 1. a) ACES soil respiration chamber b) schematic showing air flow within ACES soil chamber.

Cross Correlation of Gs and Soil Respiration from Stoy et al. 2007 (detrended for temperature effects)



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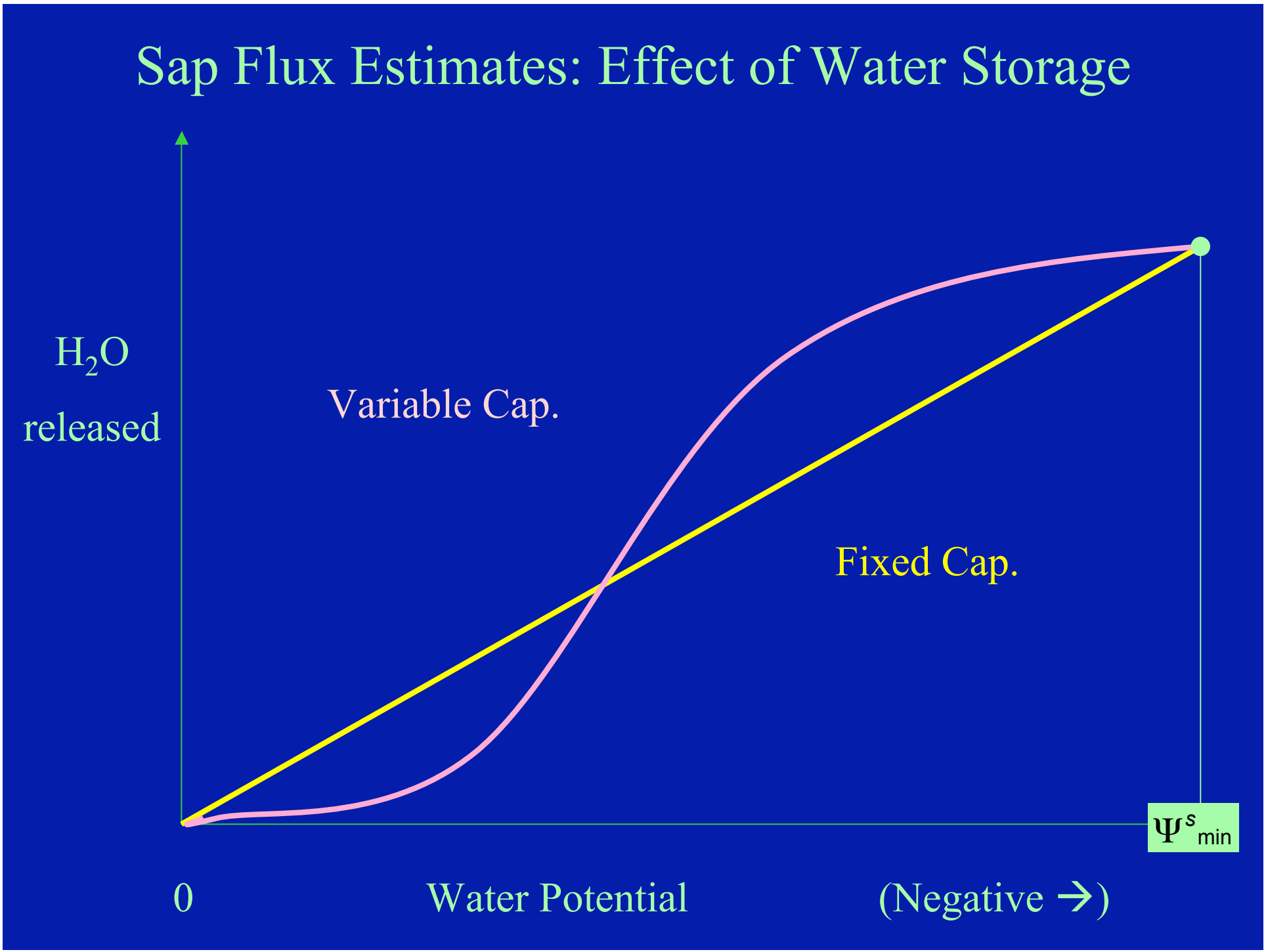
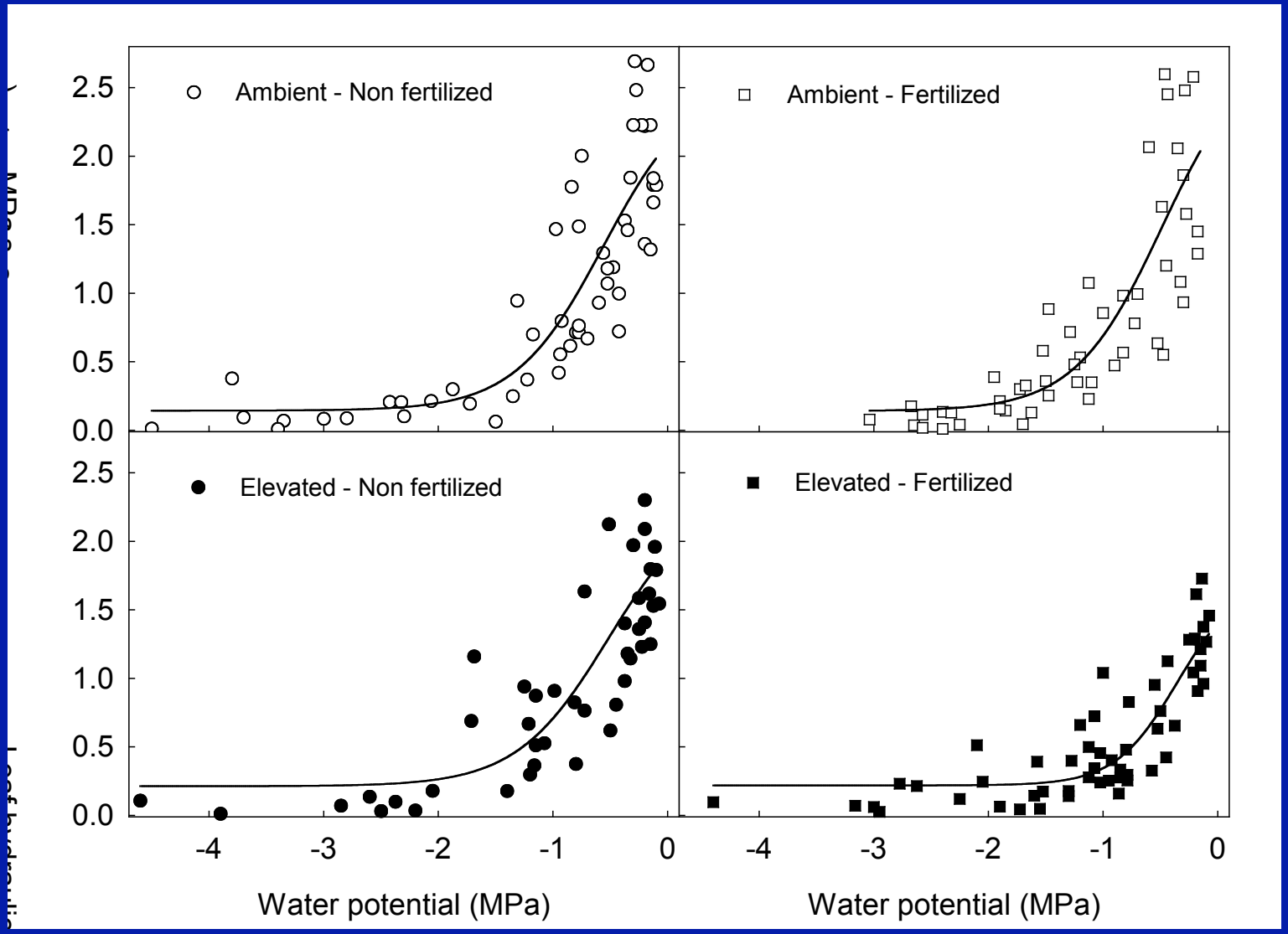
- Kurt Johnsen, Alan Gelfand, J.C. Domec, Bill Bauerle, Jim Clark
- Duke FACE and Duke Forest staffs

Sap Flux Estimates: Effect of Water Storage

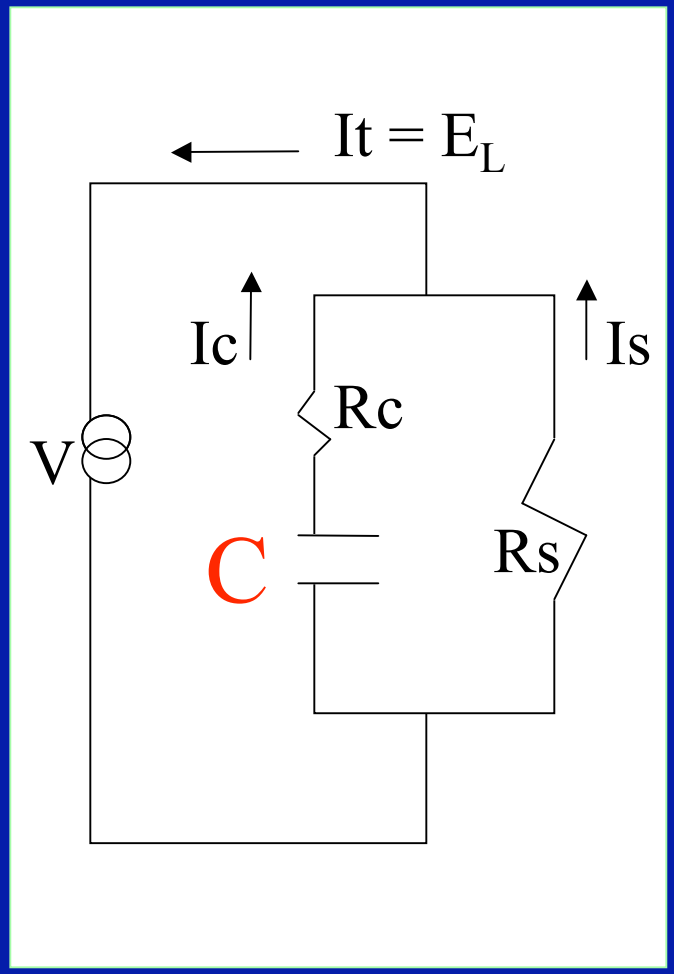


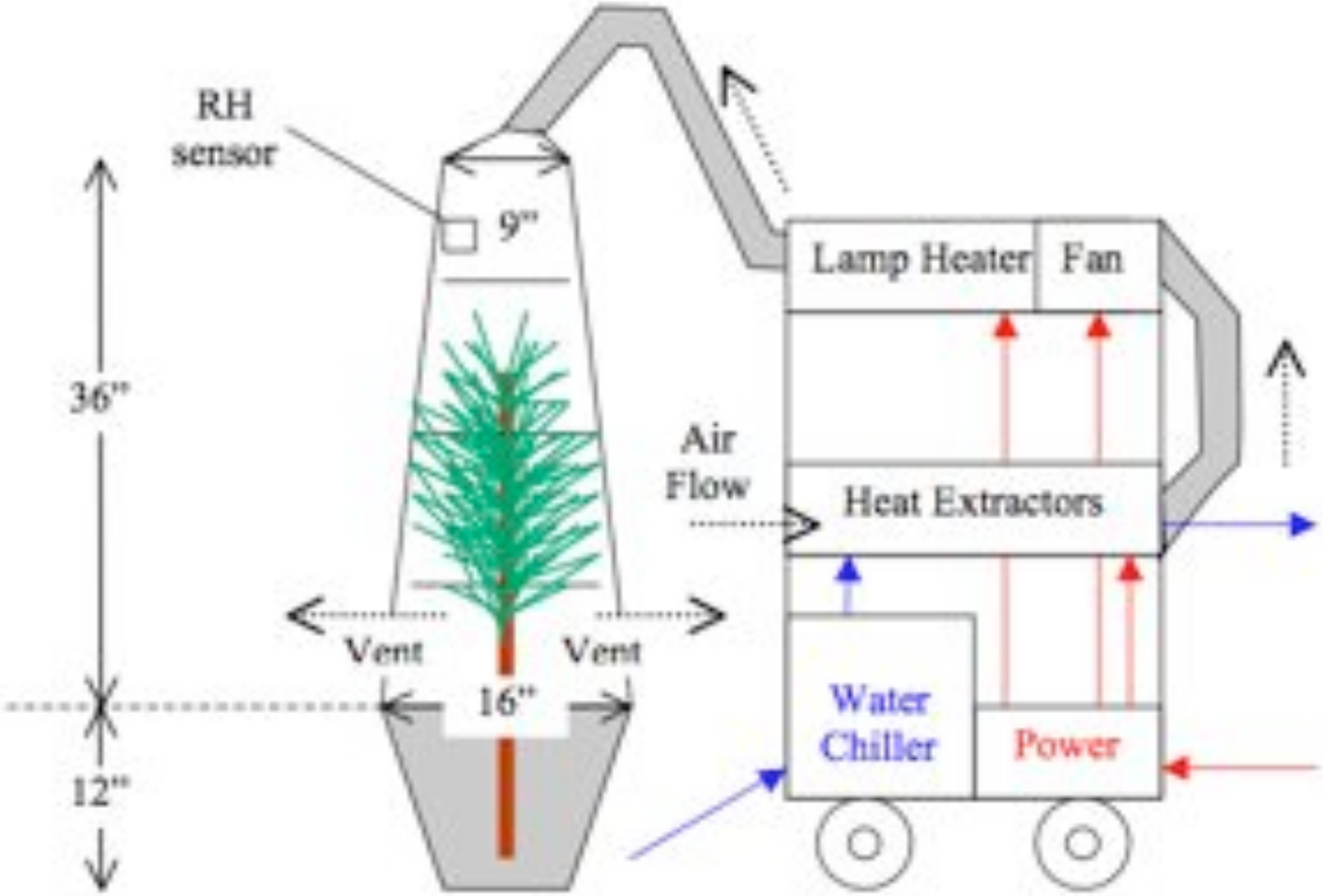
Sap Flux Estimates: Effect of Water Storage



Domec, Palmroth, Ward, Maier, Thérézien and Oren (In Review)

RC hydraulic model




RH
sensor
9"
36"
Lamp Heater
Fan
Air
Flow
Heat Extractors
Vent
Vent
16"
12"
Water
Chiller
Power